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Terahertz absorption in spintronic superlattices

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Abstract- In this work we present a theoretical investigation of optical absorption in a spintronic superlattice. It is shown that the Rashba spin-orbit interaction can be used to control the characteristics of the absorption. Our results suggest possible experiments to detect such tunable absorption spectra. The underlying mechanism is the level splitting and linear energy dispersion, both are the consequences of spin-orbit interaction. The proposed absorption properties can be useful in developing spintronic devices in the terahertz regime.

I. INTRODUCTION

The recent advancement in spintronics and spintronic materials¹ has provided new opportunities in developing new optoelectronic devices whose optical properties can be tuned by the intrinsic spin-orbit interaction (SOI). Novel spintronic material systems have been realized and advanced electronic devices have been proposed, such as spin transistors², spin waveguides³, spin filters⁴, etc.

We consider a semiconductor superlattice with alternating electron and hole layers. The electron layers are located at $z=na$ where n is an integer and a is the periodicity of the superlattice, the hole layers are located at $z=na+b$. The SOI of electrons and holes are given as

$$H_{SO}^e = \alpha(\vec{\sigma} \times \vec{p})_z \text{ and } H_{SO}^h = \beta(\vec{\sigma} \times \vec{p})_z \quad (1)$$

where α and β are Rashba SOI parameters. The original parabolic band splits into two branches and the change of the single particle energy due to the Rashba coupling is $\pm \alpha k$. The Fermi surface remains a sphere with Fermi wave vectors for electrons given as, $k_F^\pm = \sqrt{k_F^2 - k_\alpha^2} \mp k_\alpha$, where $k_\alpha = m_e \alpha^2 / \hbar^2$ and k_F is the Fermi wave vector in the absence of SOI.

II. DENSITY RESPONSE AND ABSORPTION

In the random-phase-approximation, the dielectric function of a spintronic superlattice $\mathcal{E}(q, \omega) = \mathcal{E}_1 + i\mathcal{E}_2$ can be derived^{6,7}. The real part of the dielectric function describes the dispersive properties of the system and the absorption coefficient is given as,

$$-\mathcal{E}_2 \left[2(\mathcal{E}_1 + \sqrt{\mathcal{E}_1^2 + \mathcal{E}_2^2}) \right]^{-1/2}. \quad (2)$$

The following parameters were used in our numerical calculation, $m_e = 0.04m_0$, $m_h = 0.45m_0$, where m_0 is the free electron mass. The level broadening is $\delta E = 10^{-3} E_F(0)$, and the distance between the electron layer and the adjacent hole layer is half of the superlattice periodicity, $a=2b$, where $E_F(0)$ is Fermi energy in the absence of SOI and the Coulomb interaction.

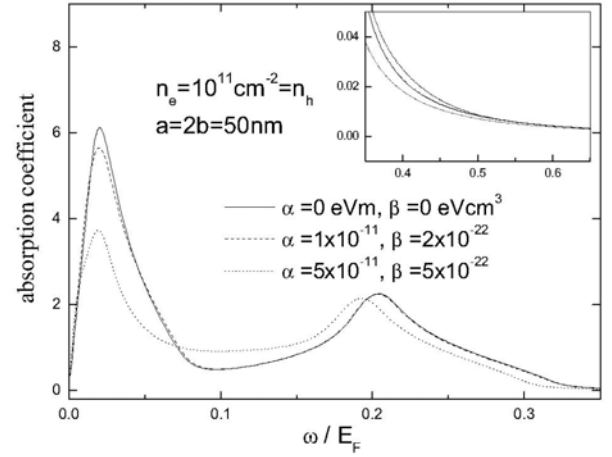


Figure 1. Absorption coefficient of spintronic superlattices for different spin-orbit couplings.

III. RESULTS AND DISCUSSIONS

For $k_z = 0.45 \times 10^6/\text{cm}$ and at $q = 0.1 k_F^0$, the absorption coefficient is shown in Fig.1 for various SOI parameters. The absorption has two well-defined peaks, correspond to direct transitions of electrons and holes. These transitions have been renormalized by the Coulomb interactions. If the spin-orbit couplings for both electrons and holes are increased, absorption intensity and the transition energy of both peaks decrease. The energy shift indicates that intralevel transitions dominate absorption at low frequencies. The reduction in absorption intensity reflects a redistribution of optical spectral weight between the plasmon and the particle-hole modes. This result suggests that the spin-orbit coupling can be used to suppress the optical absorption in spintronic systems.

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